

# Induced Contamination Predictions for JAXA's MPAC&SEED Devices

Micro **PA**rticle **C**apturer and **S**pace **E**nvironment **E**xposure **D**evice



Presented to  
The International Symposium on  
“SM/MPAC&SEED Experiment”  
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# Acknowledgement

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Image courtesy of NASA



# Introduction

**SM/MPAC&SEED Experiment deployed  
on the Service Module port-nadir side  
(View from International Space Station Aft end)**



Image courtesy of NASA

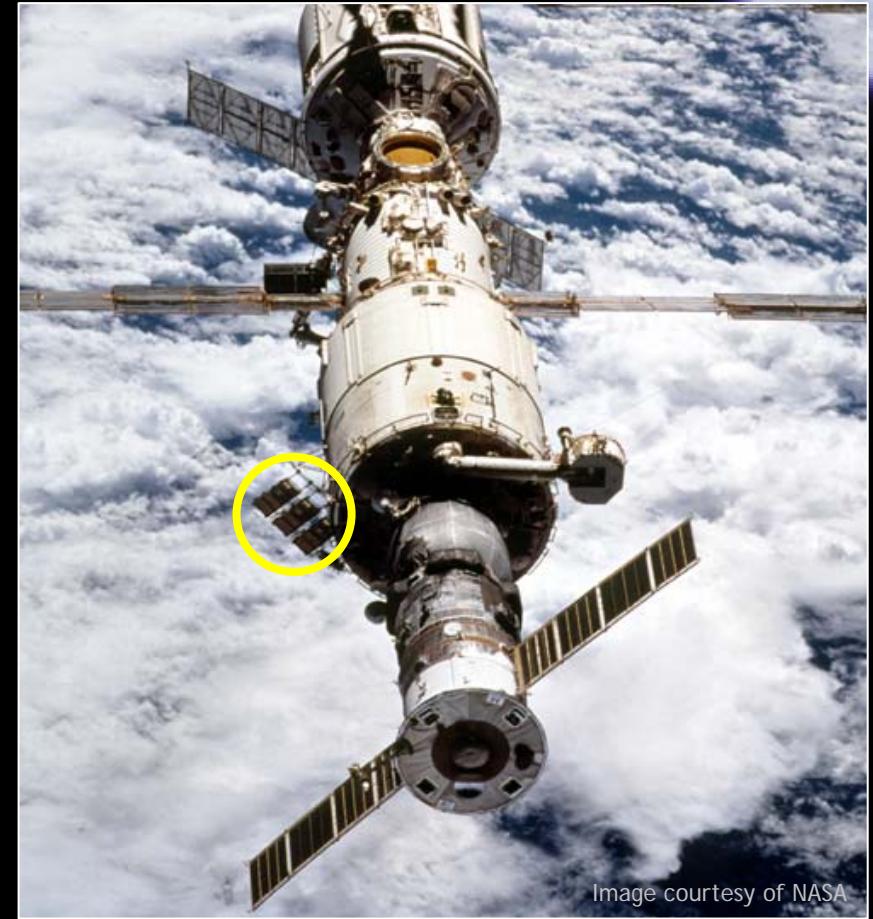


Image courtesy of NASA



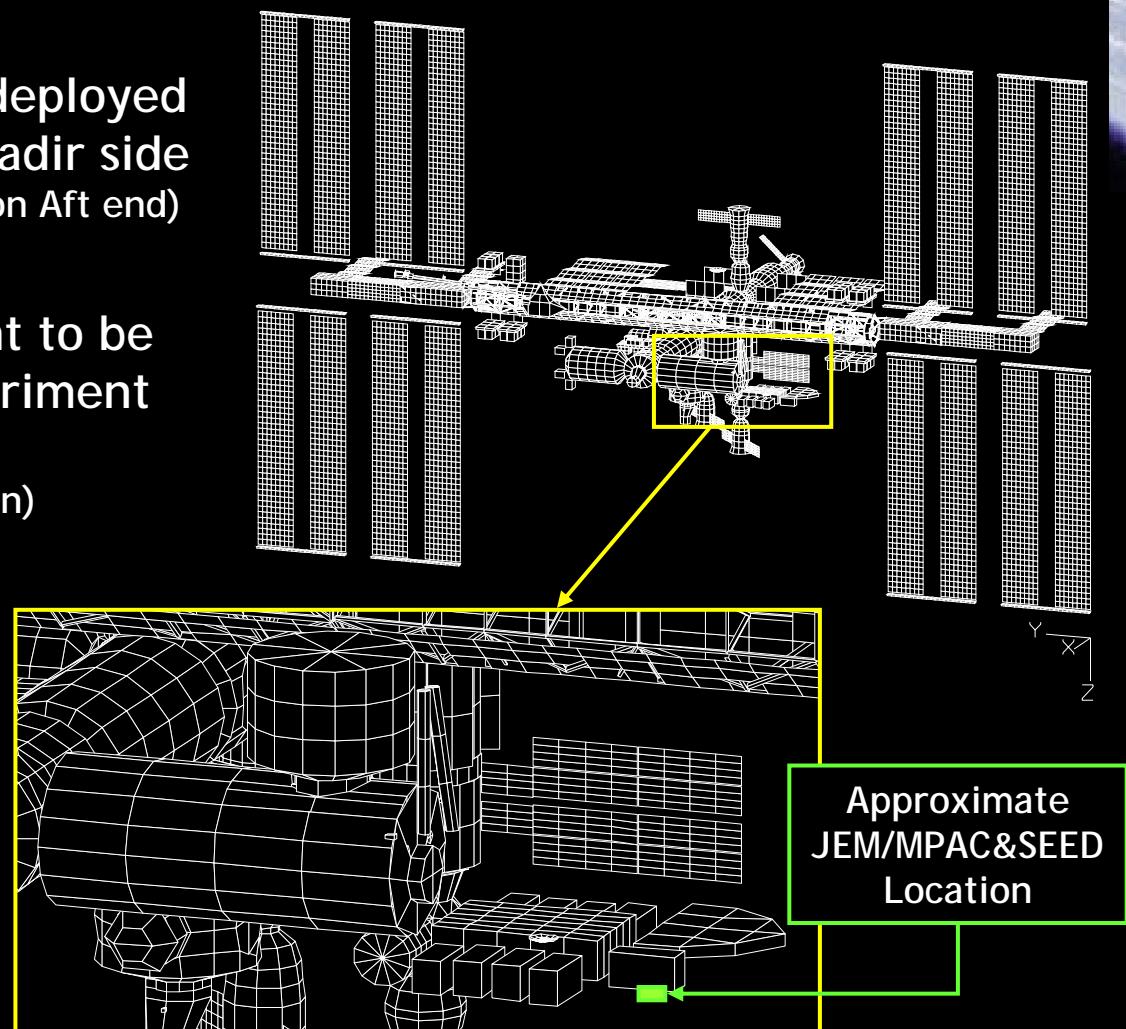
# Introduction

**SM/MPAC&SEED Experiment deployed on the Service Module port-nadir side  
(View from International Space Station Aft end)**

**JEM/MPAC&SEED Experiment to be deployed on Japanese Experiment Module Payload Site  
(Facing in RAM or +X Direction)**



Image courtesy of NASA





# Background - SM/MPAC&SEED

- ⇒ Three identical SM/MPAC&SEED units.
- ⇒ Samples on the ram and wake facing surfaces.
  - MPAC - experiment to capture micrometeoroids and space debris particles.
  - SEED - exposure experiment to characterize degradation of materials in LEO.



A single MPAC&SEED Unit  
(Ram-Facing Surface)

## References:

- Neish, et. Al. *Microparticle Capture on the International Space Station Using Aerogel and Polyimide Foam*;  
Imai, F. and Imagawa, K. *NASDA's Space Environment Exposure Experiment on ISS: First Retrieval of SM/MPAC&SEED*.

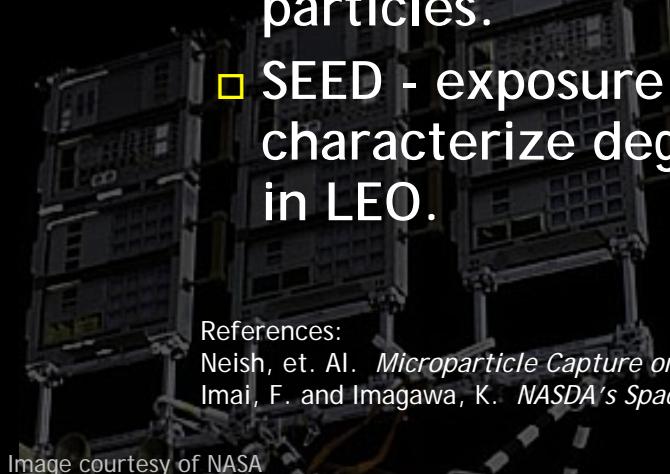
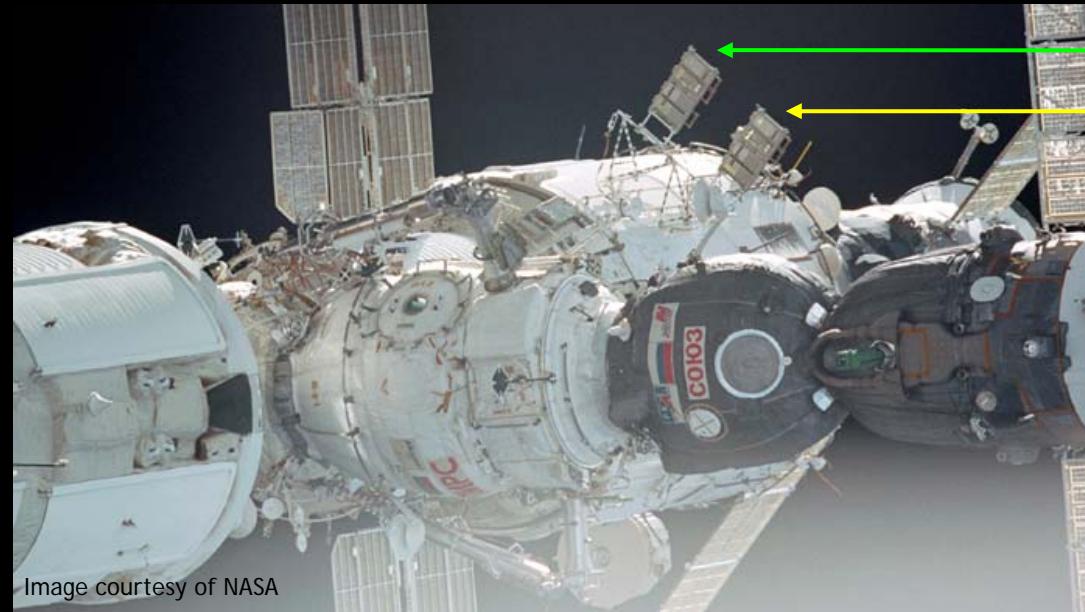


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# Background - SM/MPAC&SEED

⇒ All 3 units deployed on October 15, 2001

- First unit retrieved on August 26, 2002 - *315 Days*
- Second unit retrieved on February 26, 2004 - *865 Days*
- Third unit retrieved on August 18, 2006 - *1403 Days*



Unit 3  
Unit 2

MPAC&SEED with Unit 1 Removed  
(Unit 2 was relocated into the position previously occupied by Unit 1)

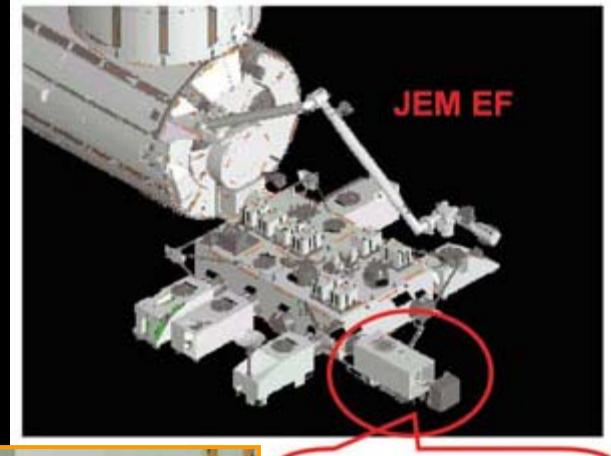
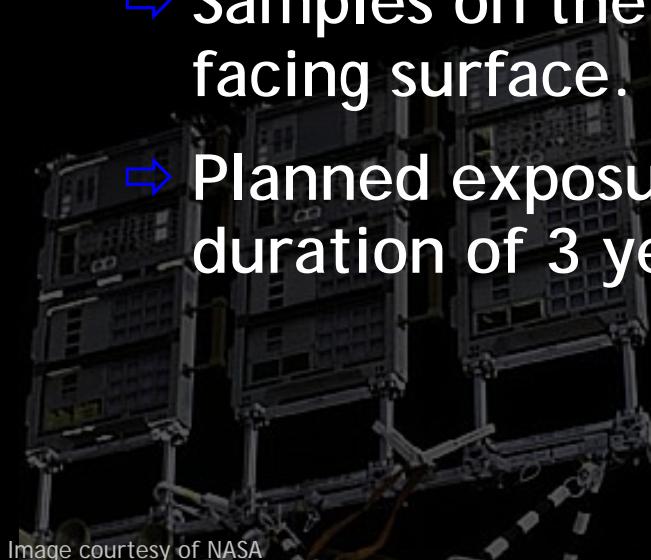


# Background - JEM/MPAC&SEED

- ⇒ JEM/MPAC&SEED to be launched on ISS Flight 2J/A (ECD March 2009) with SEDA/AP External Payload

(SEDA/AP: Space Environment Data Acquisition equipment-Attached Payload)

- ⇒ Samples on the ram facing surface.
- ⇒ Planned exposure duration of 3 years.



**SEDA-AP**  
(On orbit configuration)

JEM/MPAC&SEED



Reference:  
JAXA. Space Environment Data Acquisition equipment-Attached Payload (Website), [http://kibo.jaxa.jp/en/experiment/ef/seda\\_ap/](http://kibo.jaxa.jp/en/experiment/ef/seda_ap/), 15 Feb. 08.

Image courtesy of NASA



# Contamination Sources

## ⇒ Possible contamination sources :

- Material outgassing-induced contamination
- Thruster plume-induced contamination
- Propellant purges
- Water vents
- Self-contamination

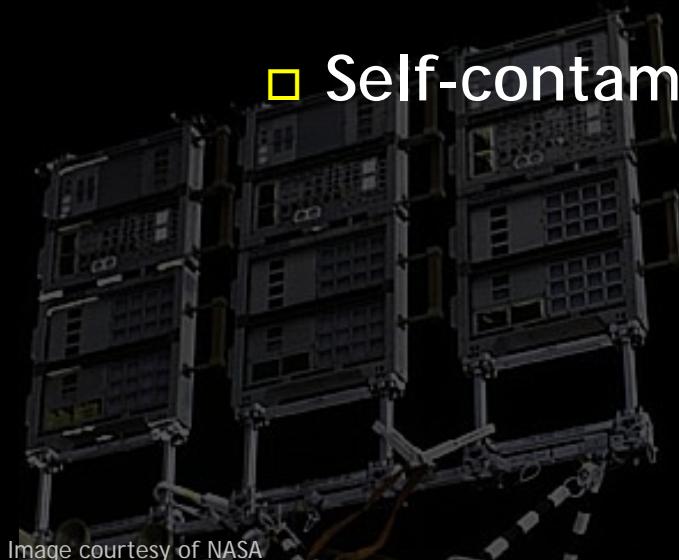


Image courtesy of NASA



# SM/MPAC&SEED

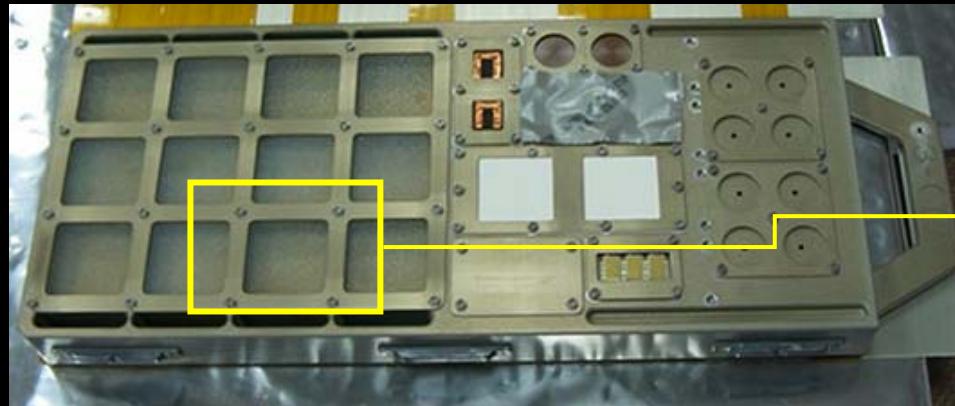
## Induced Contamination Predictions and Measurements



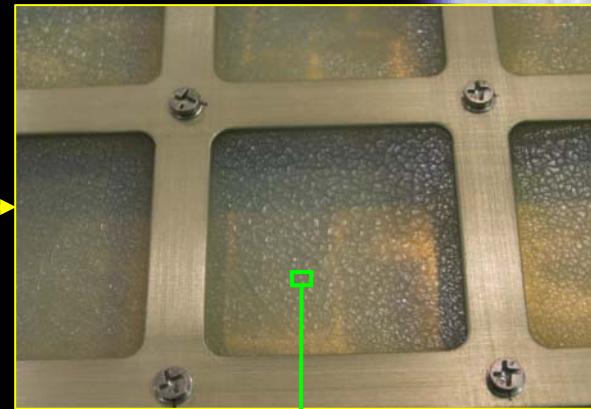
Image courtesy of NASA



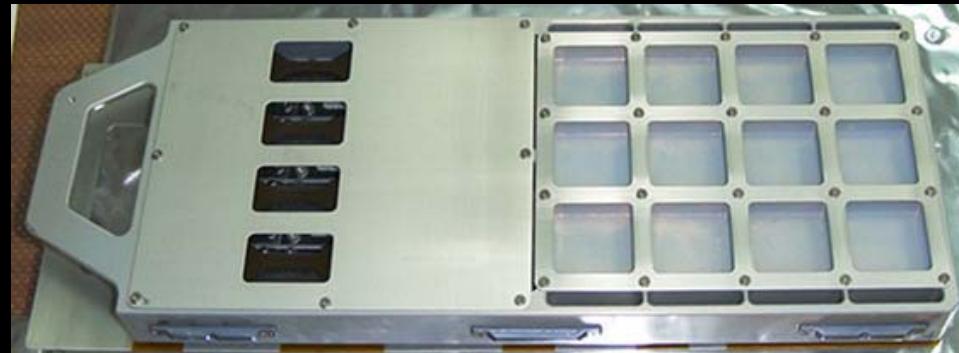
# SM/MPAC&SEED Contamination Observations



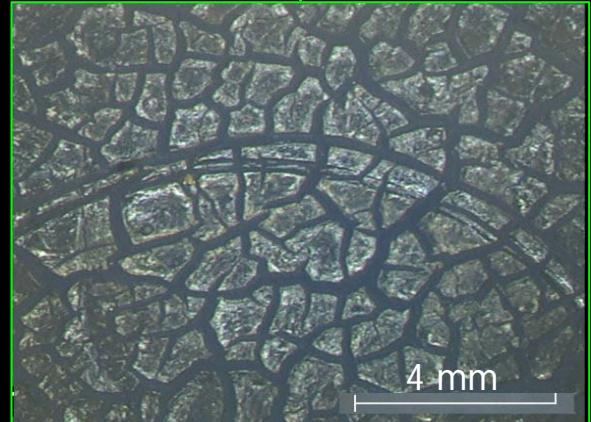
Wake face



Aerogel Sample



Ram face



Reference: Neish, Michael; Imagawa, Kichiro; Inoue, Toshihiko; Ishizawa, Junichiro; Kitazawa, Yukihito; Yamaura, Yukiko; Murakami, Atsushi; Ochi, Yoshiyuki. *Microparticle Capture on the International Space Station Using Aerogel and Polyimide Foam*.



# SM/MPAC&SEED XPS Measurements

- ⇒ X-ray Photoelectron Spectroscopy (XPS) used to measure element composition and depth profiles.
  - Element composition:
    - Silicon major constituent on ram side. Also present on wake side in lesser quantities.
    - Other constituents: oxygen, carbon, nitrogen, sodium, iron, and nickel.
  - Approximate Contamination Depth based on XPS Measurements:

Measured Contamination Depth - Angstroms (Å)			
Side	Unit 1	Unit 2	Unit 3
Ram (1)	300	750	930
Ram (2)	300	750	940
Wake (1)	55	100	110
Wake (2)	500	70	85

Reference: Baba, Naoko; Imagawa, Kichiro; Neish, Michael; and Inoue, Toshihiko. *External Contamination Control for JAXA Spacecraft*. ISTS 2004-h-06. Copyright 2004 by the Japan Society for Aeronautical and Space Sciences and ISTS.

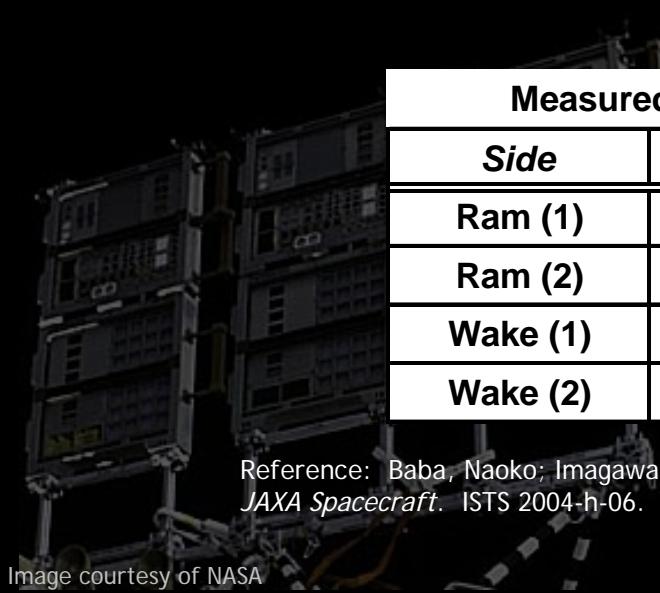


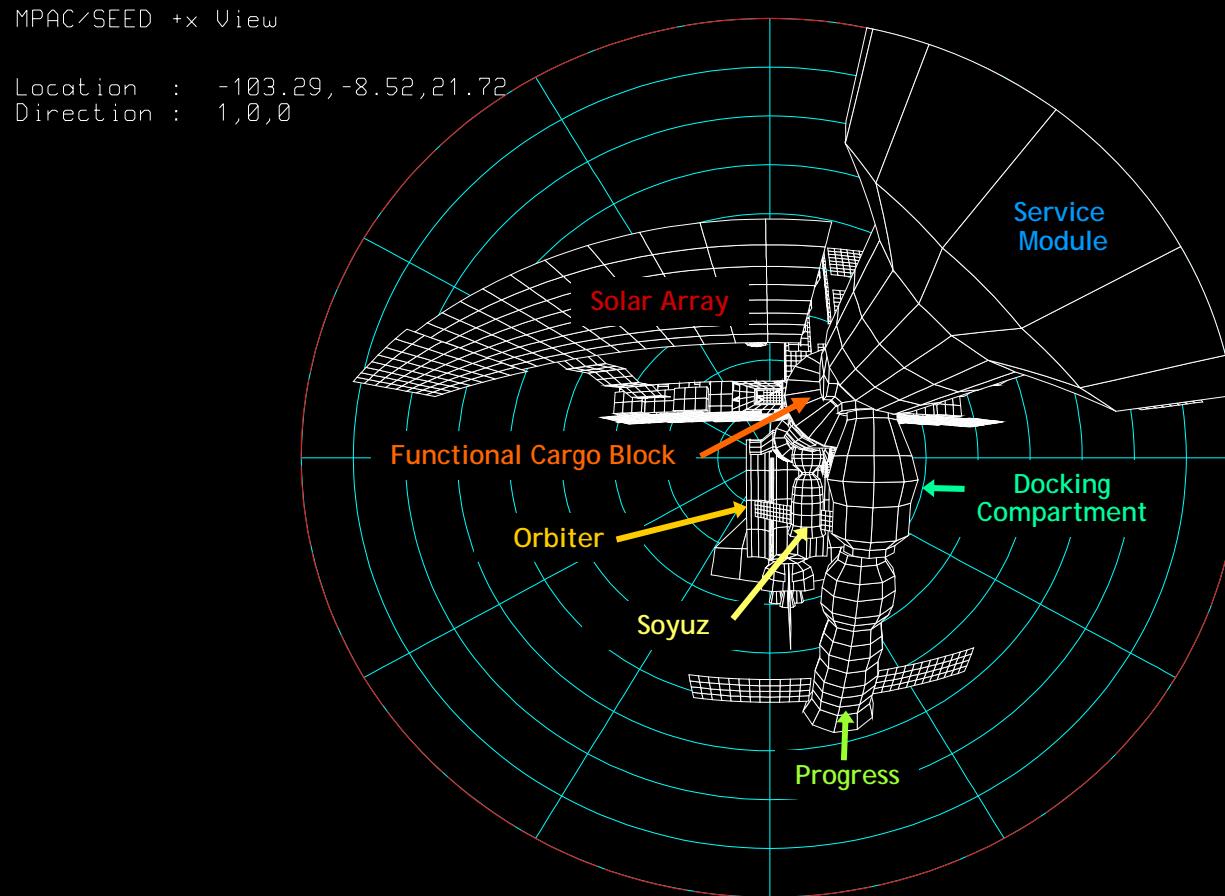
Image courtesy of NASA

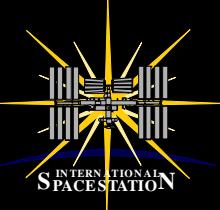


# Contamination Sources

## Material Outgassing

⇒ Hemispherical View from SM/MPAC&SEED Ram Side:

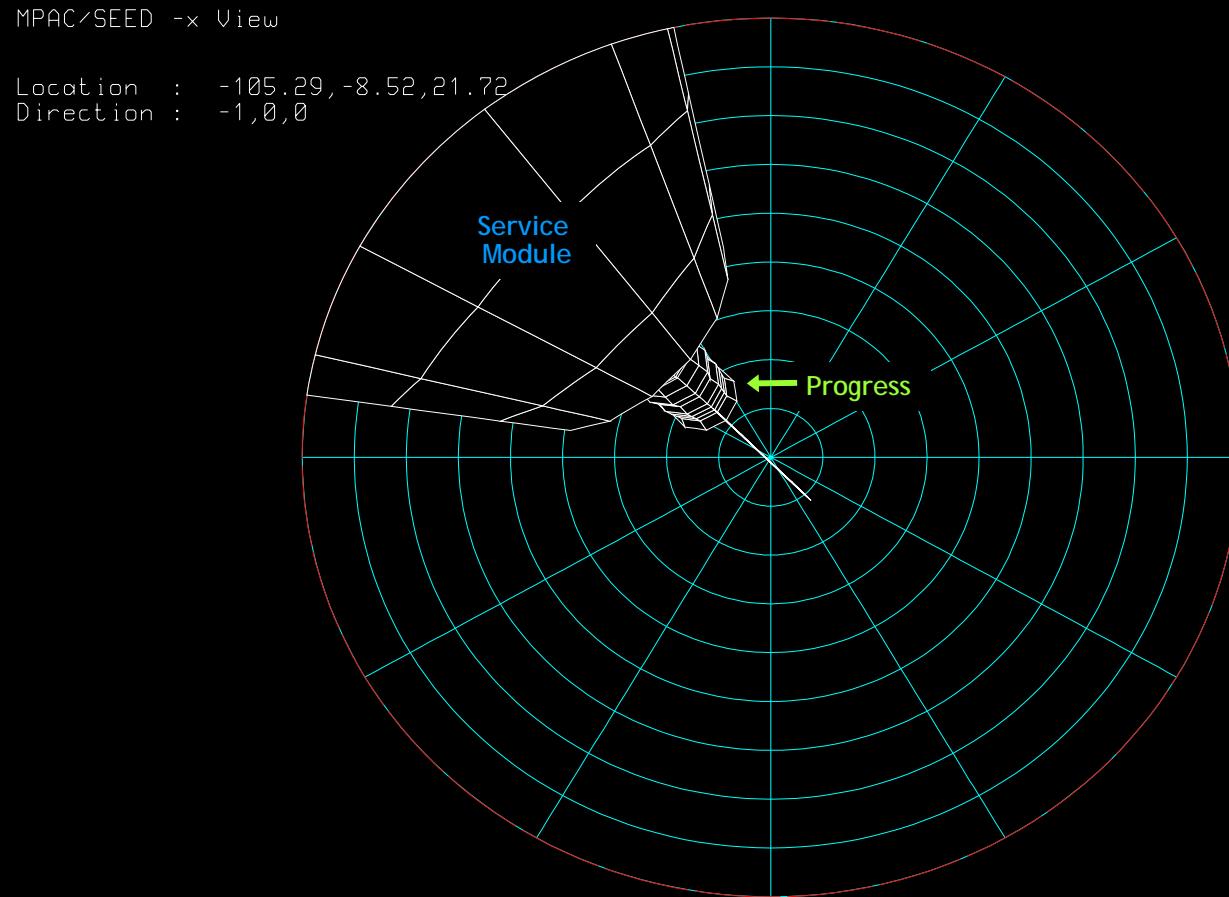




# Contamination Sources

## Material Outgassing

⇒ Hemispherical View from SM/MPAC&SEED Wake Side:





# Contamination Sources

## Thruster Plume

- ⇒ Hemispherical View to SM/MPAC&SEED wake side from Progress braking engines:

Progress PR14

Location : -150.5, -2.4, 16.9  
Direction : 0.966, -0.152, 0.209

20 Feet to Dock

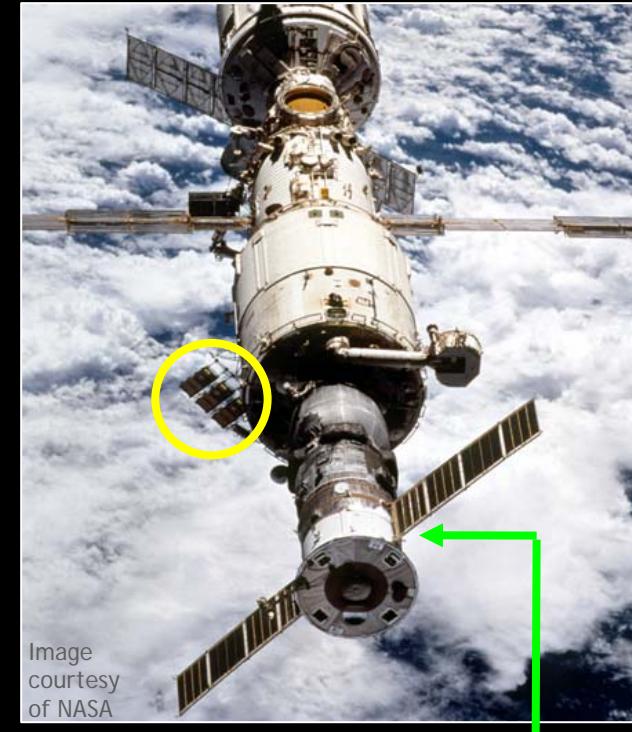
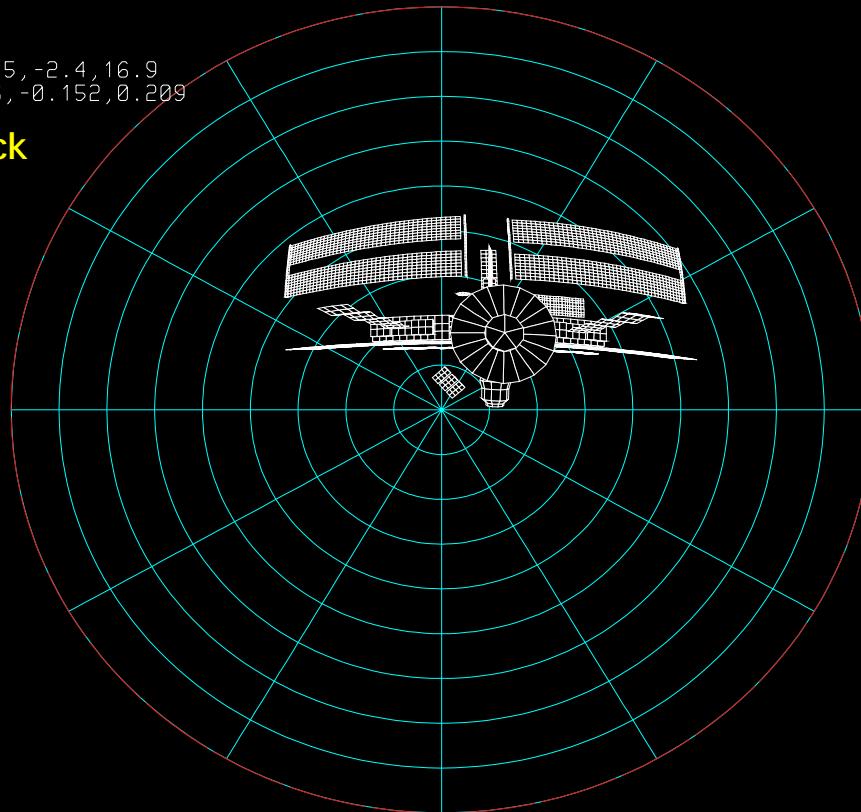


Image courtesy of NASA

Progress docked  
to aft end of ISS



# Contamination Analysis

## ⇒ Materials Outgassing Analysis:

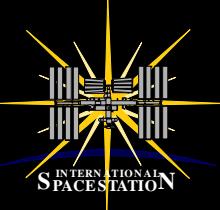
- Materials lists compiled for each ISS element.
  - Matched to available outgassing rate test data.
  - Other factors include temperature estimates, time decay scaling, and material quantity.
- Contamination calculated using an analytical model based on physical models of molecular transport.
  - Geometric model, view factor calculation, & transport routines also utilized in calculation.

## ⇒ Thruster plume contamination analysis:

- Available jet firing data used to simulate thruster firings.
- Contamination calculated with semi-empirical model based on flight experiment and chamber test data.



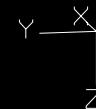
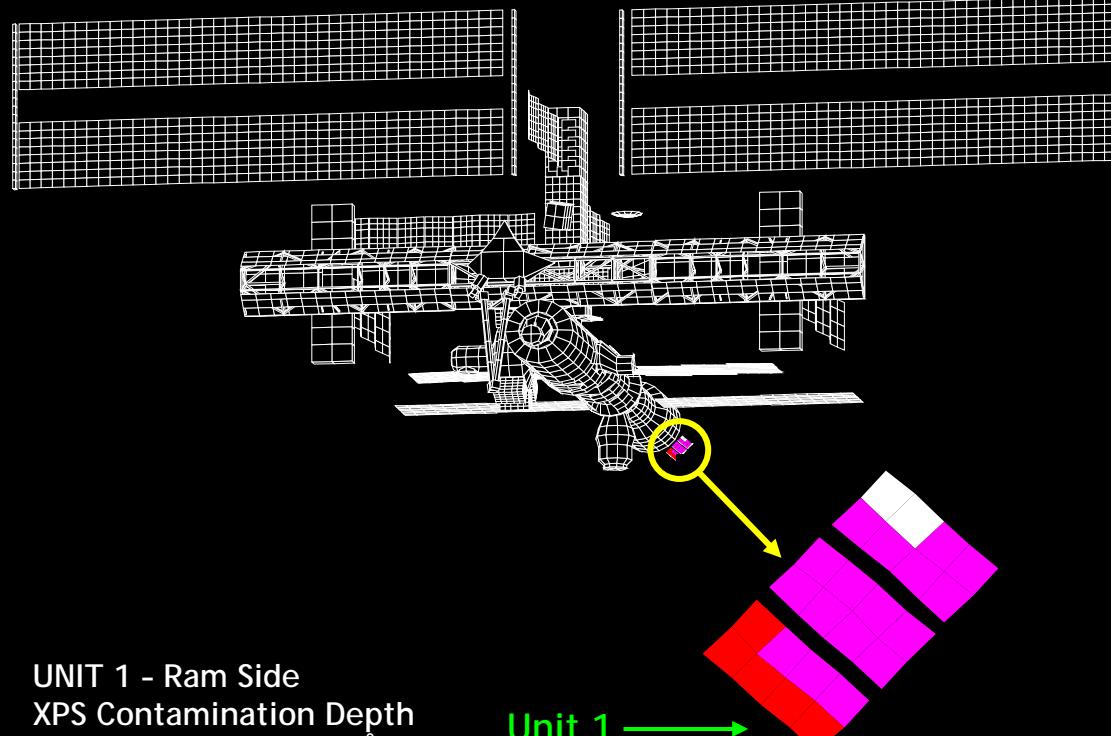
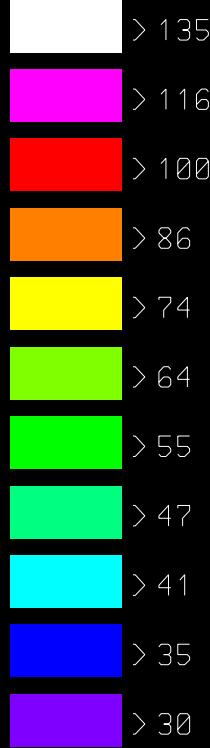
Image courtesy of NASA



# Analysis Results

## Example - SM/MPAC&SEED Unit 1 Ram Side (315 Days)

Angstroms

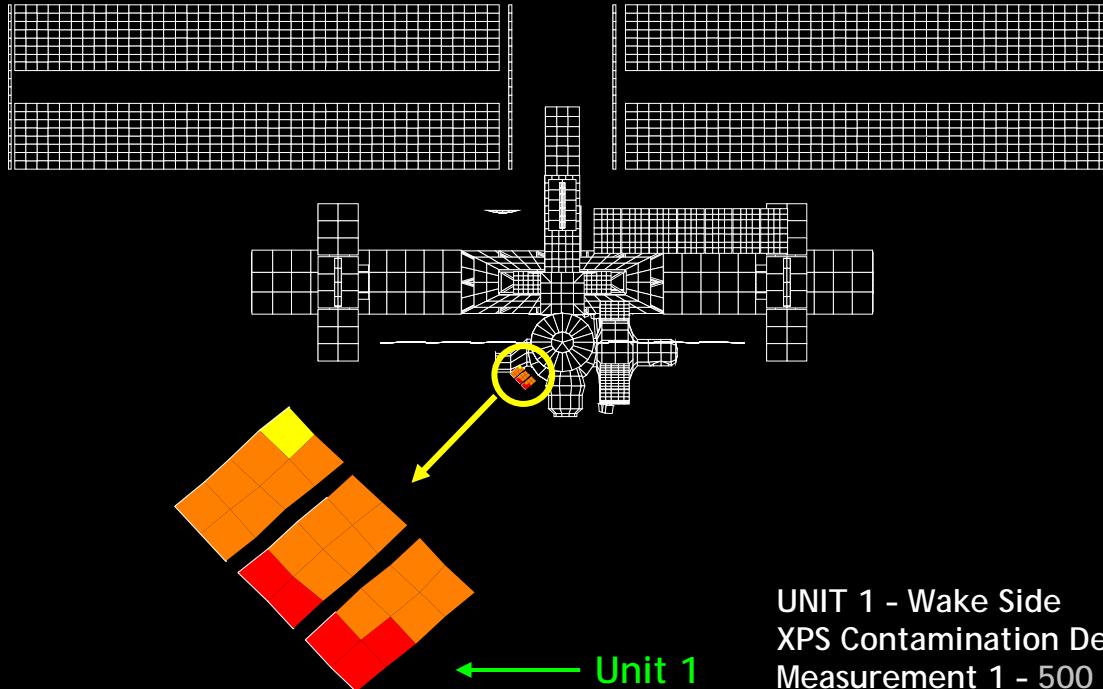
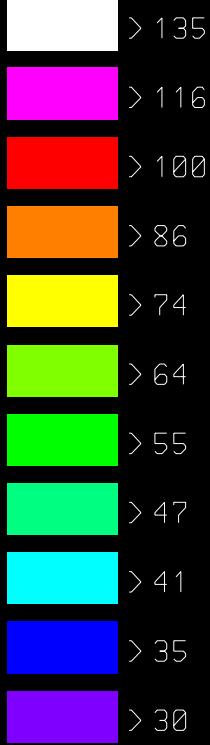




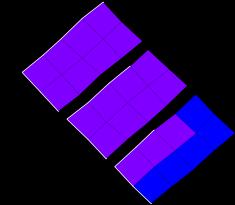
# Analysis Results

## Example - SM/MPAC&SEED Unit 1 Wake Side (315 Days)

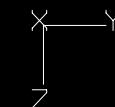
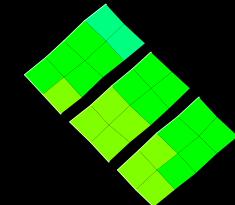
Angstroms



Contribution from  
Material Outgassing



Contribution from  
Thruster Plumes





# Analysis Summary

## SM/MPAC&SEED

- ⇒ Results for Ram Side:
  - Material outgassing induced contamination predicted and measured.
- ⇒ Results for Wake Side:
  - Contamination predicted from combination of materials outgassing and thruster plume impingement.
- ⇒ Calculated depth of contamination within a factor of 2-3 of measured contamination.

Measured Vs. Predicted Contamination Depth (Å)						
Side	Unit 1		Unit 2		Unit 3	
	Measured	Predicted	Measured	Predicted	Measured	Predicted
Ram	300	106 - 135	750	303 - 354	930	459 - 533
Ram	300		750		940	
Wake	55	86 - 103	100	186 - 237	110	317 - 414
Wake	500		70		85	

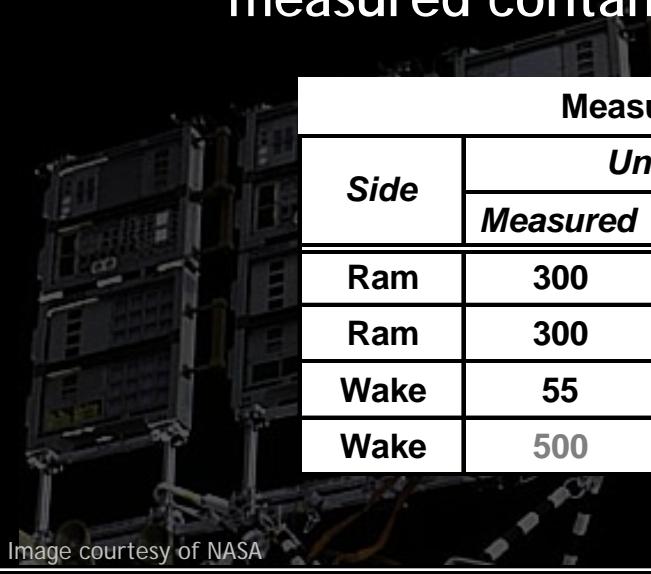


Image courtesy of NASA



# Measurements Vs. Predictions

- ⇒ Results are qualitatively consistent with XPS measurements.
  - On ram side, predictions and measurements dominated by a silicon-based contaminant.
  - Lesser degree of silicon-based contaminant predicted and measured on wake side.
  - Droplet features and presence of Nitrogen on wake side are indicative of thruster plume induced contamination.
- ⇒ Predicted results for Ram Side show good agreement with XPS measurements.
  - Possible improvements for material outgassing calculation:
    - Better characterization of the outgassing sources.
    - Additional consideration for on-orbit thermal environment.
- ⇒ XPS measurements have limitations in regard to quantifying plume contamination.
  - Thruster plumes have multiple byproducts.
  - Dominated by the liquid phase, producing droplet features and a less uniform contamination layer.

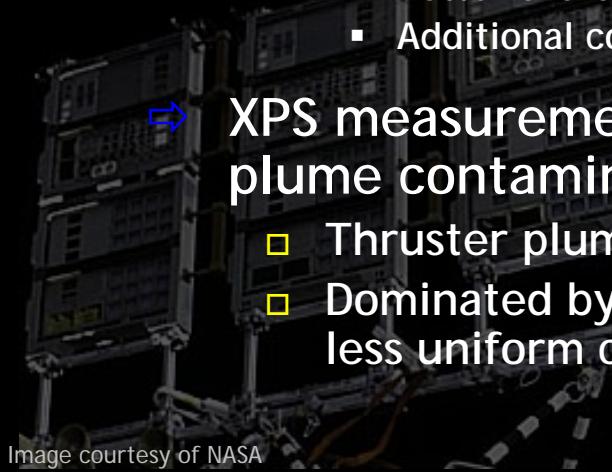
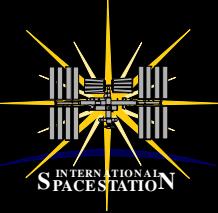


Image courtesy of NASA



# JEM/MPAC&SEED

## Induced Contamination Predictions



Image courtesy of NASA



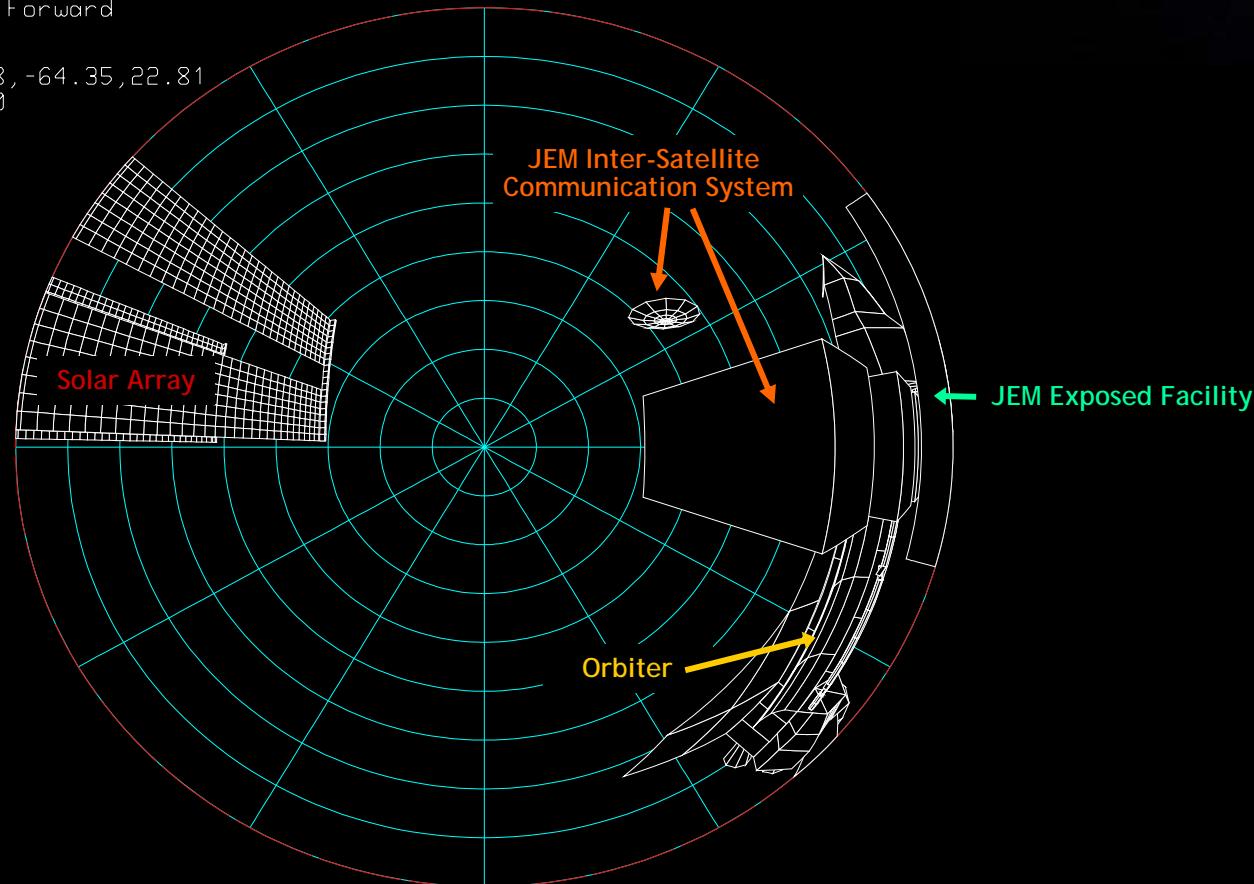
# Contamination Sources

## Material Outgassing

### ⇒ Hemispherical View from JEM/MPAC&SEED:

View from SEDA-AP Forward

Location : 44.08, -64.35, 22.81  
Direction : 1,0,0





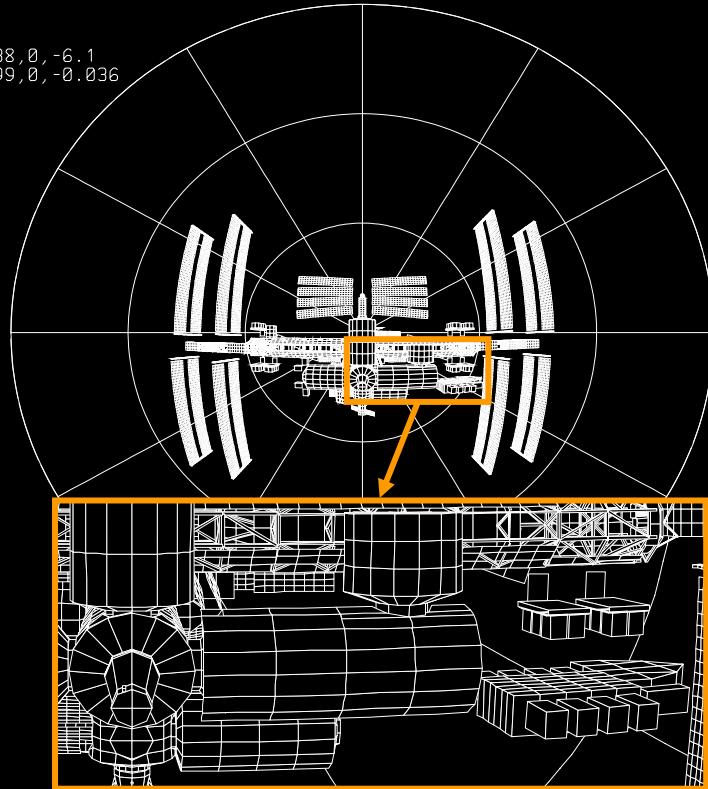
# Contamination Sources

## Thruster Plume

- ⇒ Hemispherical View to JEM/MPAC&SEED from select Orbiter thrusters:

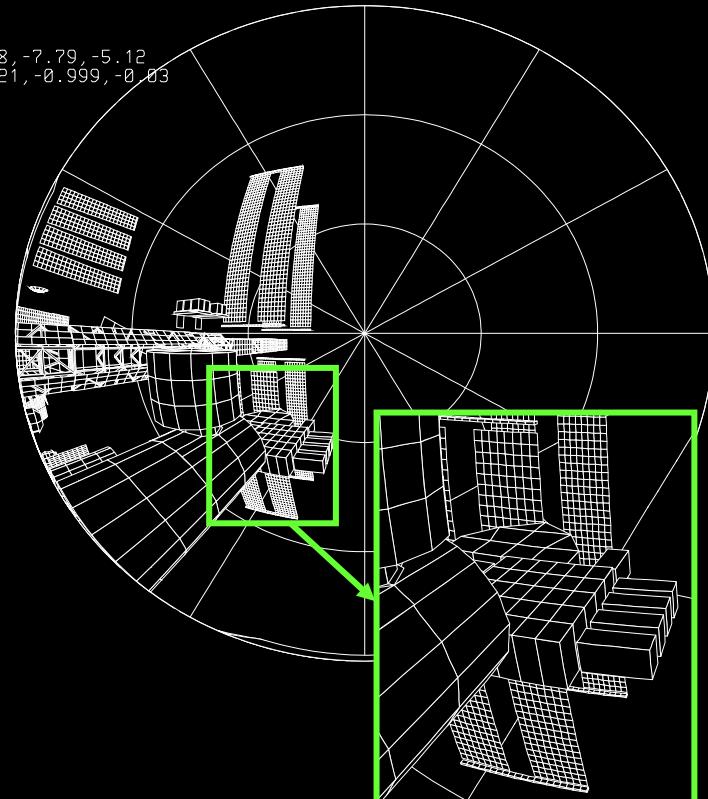
Orbiter Braking Thruster, Range = 100ft

Location : 158.38,0,-6.1  
Direction : -0.999,0,-0.036



Orbiter Side Firing Thruster, Mated

Location : 61.78,-7.79,-5.12  
Direction : -0.021,-0.999,-0.03





# Analysis Results

## JEM/MPAC&SEED

- ⇒ Material outgassing is the primary source of induced contamination predicted.
  - Depth of contamination layer dependent on JEM/MPAC&SEED surface temperature.
  - Majority of outgassing contamination comes from JEM hardware due to close proximity and view factor.
- ⇒ Orbiter thruster plume induced contamination predicted to be negligible.

**Predicted Contamination Depth (Å) due to Material Outgassing Sources  
(for 3 year exposure duration)**

JEM/MPAC&SEED Temperature	JEM (EF and ICS)	ISS (Solar Array & Orbiter)	Total
-40°C	258.7 Å	3.3 Å	262 Å
-10°C	100.2 Å	3.3 Å	103 Å
25°C	41.5 Å	2.9 Å	44 Å

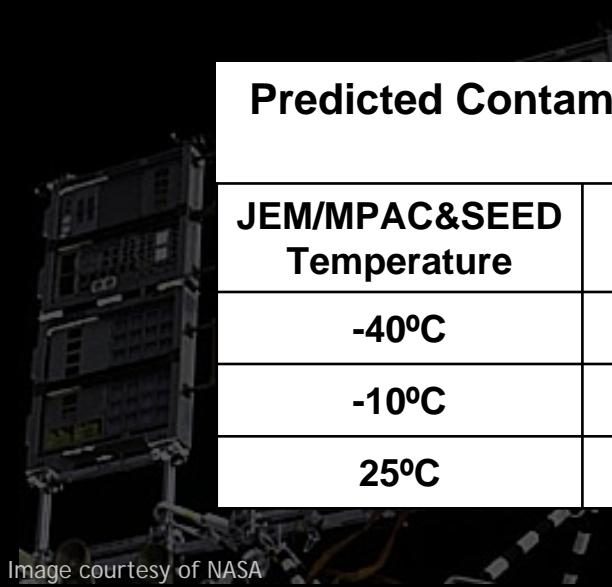


Image courtesy of NASA



# Conclusions

- ⇒ Externally mounted ISS payloads are exposed to the induced ISS environment, including material outgassing and thruster plume contamination
- ⇒ The Boeing Space Environments Team developed analytical and semi-empirical models to predict material outgassing and thruster plume induced contamination.
- ⇒ JAXA's SM/MPAC&SEED experiment provides an unique opportunity to compare induced contamination predication with measurements.
  - Analysis results are qualitatively consistent with XPS measurements.
  - Calculated depth of contamination within a factor of 2-3 of measured contamination.
  - Represents extremely good agreement, especially considering long duration of experiment and number of outgassing sources.
  - Despite XPS limitations in quantifying plume contamination, the measured and predicted results are of similar scale for the wake-facing surfaces.
- ⇒ JAXA's JEM/MPAC&SEED experiment will also be exposed to induced contamination due to JEM and ISS hardware.
  - Predicted material outgassing induced contamination to JEM/MPAC&SEED ranges from 44Å to 262Å (depending on surface temperature) for a 3 year exposure duration.

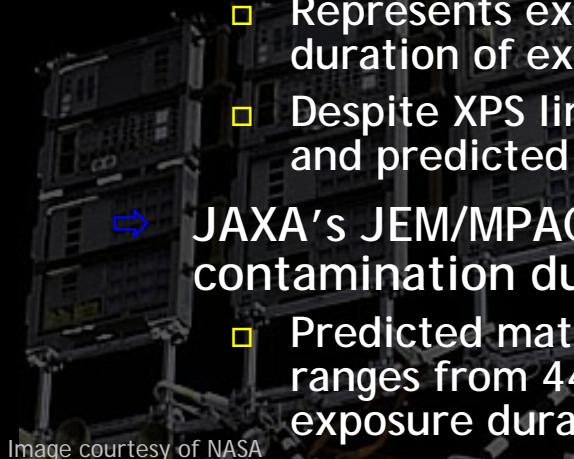


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